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TRANSMITTAL LETTER

Sir:

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1. This Transmittal Letter;
2. Patent Application (Specification - 9 sheets, ~~including cover page~~, Claims - 3 sheets, Abstract - 1 sheet, Drawings - 7 sheets);

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Respectfully submitted,

Date: 11/13/99

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LOW COST MOTOR DESIGN FOR RARE-EARTH-MAGNET LOUDSPEAKERS

Reference to Related Applications

This application claims the benefit of priority of United States Patent Application Serial No. 60/108,338, filed November 13, 1998.

Background of the Invention

The invention relates to loudspeakers and to low-cost magnetic motors for use in loudspeakers. The invention has application, among other places, in cell phones, pagers, MP3 players, and other appliances where weight and size are factors.

A large percentage of loudspeakers are electrodynamic speakers. Such speakers employ a magnetic driver to produce movement of a diaphragm (typically cone or dome-shaped) which, in turn, causes sound. A typical loudspeaker includes a fixed magnet and voice coil. The magnet may be mounted to the rear of the frame behind the diaphragm. A magnetic "circuit" may be utilized to focus and, therefore, intensify the magnetic field in a region referred to as the "air gap". The voice coil is disposed adjacent the magnet and, preferably, within the air gap. The coil typically wire formed about a cylindrical support or "former" which, itself, is attached to the diaphragm.

In operation, electrical audio signals from an amplifier are applied to the voice coil producing a varying electromagnetic field around the coil. The electromagnetic field interacts with the magnetic field produced by the magnet. The magnet is securely fixed to the frame and the voice coil is movable, so the voice coil moves as the two fields interact. Because the voice coil is coupled to the diaphragm via the support, its movement causes the diaphragm to vibrate. The vibration of the diaphragm causes air around the speaker to pressurize and depressurize producing sound waves in the air.

The high energy density of rare earth materials such as neodymium boron iron is attractive for creating and miniaturizing shielded loudspeaker magnets. The magnet rings or discs can best be installed as cores on the inside of the transducers voice coil for easy manufacturing. The maximum storable and extractable energy is then limited by the voice coil diameter and can be increased only by the height of the neodymium slug.

An object of this invention is to provide improved loudspeakers and, more particularly, improved magnetic motors for loudspeakers.

A further object of the invention is to provide such motors that utilize rare earth magnets.

A still further object of the invention is to provide such motors as permit construction of lower impedance, higher B x L neodymium motors for driving loudspeakers.

Yet a still further object is to provide such motors as eliminate the need for multiple magnets and expensive edge winding and offers greater freedom in amplifier matching for best overall system value.

Still yet further objects of the invention are to provide such motors as permit the construction of low voltage sound systems for portable talking appliances like cell phones, note book and palm size computers, pagers, and other interactive wireless appliances.

Summary of the Invention

The foregoing objects are attained by the invention which provides, in one aspect, a loudspeaker magnetic motor that utilizes a voice coil with two or more wire coils that are connected in parallel and that are layered on top of one another.

Further aspects of the invention provide motors as described above in which the coils are formed from wires that have round cross-sections.

Still further aspects of the invention provide motors as described above in which a first coil is disposed about a voice coil former and in which a second coil is disposed about the first coil.

The invention provides, in other aspects, a motor as described above which includes, as a magnetic field source, a permanent magnet and, more particularly, a permanent magnet that includes a rare earth metal. Related aspects of the invention provide a motor as described above in which the magnetic field source comprises neodymium. One such source is a neodymium boron iron magnet.

Another aspect of the invention provides a motor as described above in which the permanent magnet is "coin shaped" or, more particularly, has a cylindrical cross-section.

Still other aspects of the invention provide a loudspeaker that includes a magnetic motor as described above.

These and other aspects of the invention are evident in the drawings and in the description that follows.

Loudspeaker magnetic motors as provided by the invention feature several advantages over the prior art. They provide a low cost, practical method for maximizing the available force $F = B \times L \times I$ from any "thick" rare earth magnet motor, i.e., one with a permanent magnet with an operating point $B/H >= 2.5$. This leads to an improved cost performance ratio by permitting construction of lower impedance, higher $B \times L$ neodymium motors for driving loudspeakers. This also eliminates the need for multiple magnets and expensive edge winding and offers greater freedom in amplifier matching for best overall system value.

Brief Description of the Drawings

A more complete understanding of the invention may be attained by reference to the drawings, in which:

Figure 1 is a graph showing relationships between flux density (B), coercive force (H) and operating points for various magnetic materials and configurations;

Figure 2A shows a cross section of conventional magnetic motor; Figure 2B details a portion of the drawing shown in Figure 2A;

Figure 3A shows a cross section of magnetic motor using edge winding; Figure 3B details a portion of the drawing shown in Figure 3A;

Figure 4A shows a cross section of neodymium boron iron magnetic motor using a winding according to the invention; Figure 4B details a portion of the drawing shown in Figure 4A; and

Fig. 5 is a graph showing increased bass output using same coil and magnet in a 4-layer versus a "tandem" configuration after normalizing curves at 500Hz.

Fig. 6 is a graph showing impedance vs frequency for a magnetic motor according to the invention vs that of conventional motor, e.g., of the type shown in Figure 2; and

Figure 7 shows a loudspeaker according to the invention.

Detailed Description of the Illustrated Embodiment

The driving force available to a speaker is B x L x I, where B is the flux density, L the length of coil wire and I the current through the coil wire. For a fixed magnet diameter and gap, the height d and thus the magnetic operating point B/H are rapidly reached where the flux density B in the gap increases very little while the magnet cost increases as its height increases. The full energy product B*H can only be realized for B/H=1. See Figure 1.

Figures 2A and 2B show cross sections of conventional magnetic motor 10. The illustrated motor includes a permanent magnet 12 and a magnetic "circuit" comprising top and bottom plates 14, 16. The plates focus the field of magnet 12 in a gap 18, which is shown in greater detail in Figure 2B. A voice coil 20 is formed about support (or former) 22. The illustrated coil comprises two layers of round wire, i.e., wire having a round cross-section.

The motor 10 of Figures 2A - 2B is best suited to "low" magnetic operating-point (B/H) systems with d/w >= 2.5, where d is the height of the magnet and w is the width of the gap. A taller magnet with B/H >= 2.5 improves mainly the temperature stability of the system.

One way to increase the drive force of a magnetic motor of the type shown in Figures 2A - 2B is to utilize stacked magnets of opposing polarity. This can be costly, though effective.

Another way is to use and "edge winding" configuration of the type shown in Figures 3A - 3B. Here, the active coil wire length L is increased by winding a "flat wire" 24A (i.e., a wire of flattened cross-section) about the support former. This configuration is particularly useful when flux density B itself cannot be improved and, hence, only an increase of wire length L (or current I) can increase the extractable force.

Unfortunately, the process of flat wire coil winding is tedious and too slow for low cost, high volume production. In practice, edge-winding also leads to either heavy or high resistance coils: The coil mass becomes prohibitive if a low resistance is to be maintained or the resistance becomes impracticably high thus reducing the current I.

Another drawback is unfilled gap space needed to clear the return wire 24B, which occupies a portion of the gap 18 and, hence, prevents extraction of energy that might otherwise be attained from the magnetic field within gap.

Figures 4A - 4B depict a magnetic motor according to one practice of the invention. The motor includes a magnet 12' that preferably comprises a rare earth metal and, more preferably, neodymium. Still, more preferably, it is a neodymium boron iron magnet. Top and bottom plates 14, 16 are comprised of materials of the type conventionally used in connection with such magnets 12'.

Voice coil 20' comprises two or more windings of wire or other conductor of the type conventionally used in rare earth magnetic motors. Unlike the conventional configurations (e.g., of the type shown in Figures 2A - 2B), the multiple windings of coil 20' are connected in parallel. Thus, a first winding is disposed about the cylindrical former 22, a second winding is disposed about the first, a third winding about the second, and so forth. The windings are connected in parallel to one another.

A motor according to the invention emulates the edge-wound configuration, without the latter's inherent disadvantages. Such winding multiplies the number of turns L for a given gap length just like a normal round wire coil. The stacked coil sections are then connected in parallel.

In a configuration with multiple windings, for a given applied voltage, the current I increases four-fold compared a conventional two-layer coil (e.g., as shown in Figure 2) with the same number of turns. The resistance is one fourth of that of the normal coil and the effective number

of turns L is cut in half. However, the number of turns L for a given coil height is SQRT(2) times greater than a single-wire coil of the same resistance and height. Coil thickness of the tandem coil is SQRT(2) times that of a single wire coil of equal area.

For a given flux density B, the B x L x I - product is therefore SQRT(2) times larger than a single wire coil of equal area while the mass is approximately the same.

By using a neodymium boron magnet, the motor of Figures 4A - 4B permit increasing the gap width without suffering the loss of flux density associated with ferrite magnets when widening the magnet gap. Furthermore they enables powerful magnet designs where a "thick" neodymium magnet can be on the inside of the voice coil and still offer a high level of extractable energy. Benefiting applications are hands free cell phones, pagers, MP3 players, and other new interactive talking inter net appliances where weight and size are crucial to the product acceptance.

Fig. 5 is a graph shows increased bass output using same coil and magnet in a 4-layer versus a "tandem" configuration after normalizing curves at 500Hz. Fig. 6 is a graph showing impedance vs frequency for a magnetic motor according to the invention vs that of conventional motor, e.g., of the type shown in Figure 2.

Motors according to the invention fulfill the following significant benefits:

1. Increase of 33% in B x L product while maintaining same moving mass (See Figure 5);

2. Low drive impedance for improved power intake in low supply voltage applications (See Figure 6, yellow curve);

3. Reduced inductance compared to normal multi-layer coil also improves high frequency response (See Figure 6);

4. Low cost construction and manufacturing;

5. Maintains the temperature stability of a high magnetic operating point;

6. Enable four- and six-layer coil construction without undue mass increase;

7. Better utilization of all metal and magnetic materials.

Figure 7 shows a loudspeaker according to the invention. The speaker is of conventional operation and construction, except insofar as it includes a magnetic motor of the type shown in Figures 4A - 4B and described above.

Described above is a improved magnetic motor and loudspeaker according to the invention. It will be appreciated that the embodiment shown in the drawings and described above are merely examples of the invention and that other motors and loudspeakers incorporating the teachings hereof fall within the scope of the invention, of which I claim:

1. A loudspeaker magnetic motor comprising

a voice coil

the voice coil comprising two or more wire coils,

the wire coils being connected in parallel and being layered on top of one another.

2. A loudspeaker magnetic motor according to claim 1, wherein at least one of the coils comprises a conductor having a round cross-section.

3. A loudspeaker magnetic motor according to claim 2, wherein the coils comprise wires having round cross-sections.

4. A loudspeaker magnetic motor according to claim 2, in which

a first wire coil is disposed about a support, and

a second wire coil is disposed about the first coil.

5. A loudspeaker magnetic motor according to claim 1, comprising a magnetic field source.

7. A loudspeaker magnetic motor according to claim 5, wherein the magnetic field source is a permanent magnet.

8. A loudspeaker magnetic motor according to claim 7, wherein the magnetic field source comprises a rare earth metal.

9. A loudspeaker magnetic motor according to claim 8, wherein the magnetic field source comprises neodymium.

10. A loudspeaker magnetic motor according to claim 9, wherein the magnetic field source comprises a neodymium boron iron magnet.

11. A loudspeaker magnetic motor according to claim 10, wherein the neodymium boron iron magnet has a cylindrical cross-section.

12. A loudspeaker comprising

a voice coil

the voice coil comprising two or more wire coils,

the wire coils being connected in in parallel and being layered on top of one another.

13. A loudspeaker according to claim 12, wherein at least one of the coils comprises a conductor having a round cross-section.

14. A loudspeaker according to claim 13, wherein the coils comprise wires having round cross-sections.

15. A loudspeaker according to claim 13, in which

a first wire coil is disposed about a support, and

a second wire coil is disposed about the first coil.

16. A loudspeaker according to claim 12, comprising a magnetic field source.

18. A loudspeaker according to claim 16, wherein the magnetic field source is a permanent magnet.

19. A loudspeaker according to claim 18, wherein the magnetic field source comprises a rare earth metal.

20. A loudspeaker according to claim 19, wherein the magnetic field source comprises neodymium.

21. A loudspeaker according to claim 20, wherein the magnetic field source comprises a neodymium boron iron magnet.

22. A loudspeaker according to claim 21, wherein the neodymium boron iron magnet has a cylindrical cross-section.

Abstract

A loudspeaker magnetic motor utilizes a voice coil with two or more wire coils that are connected in parallel and that are layered on top of one another. The motor utilizes, as a magnetic field source, a permanent magnet and, more particularly, a permanent magnet that includes a rare earth metal such as a neodymium boron iron magnet.

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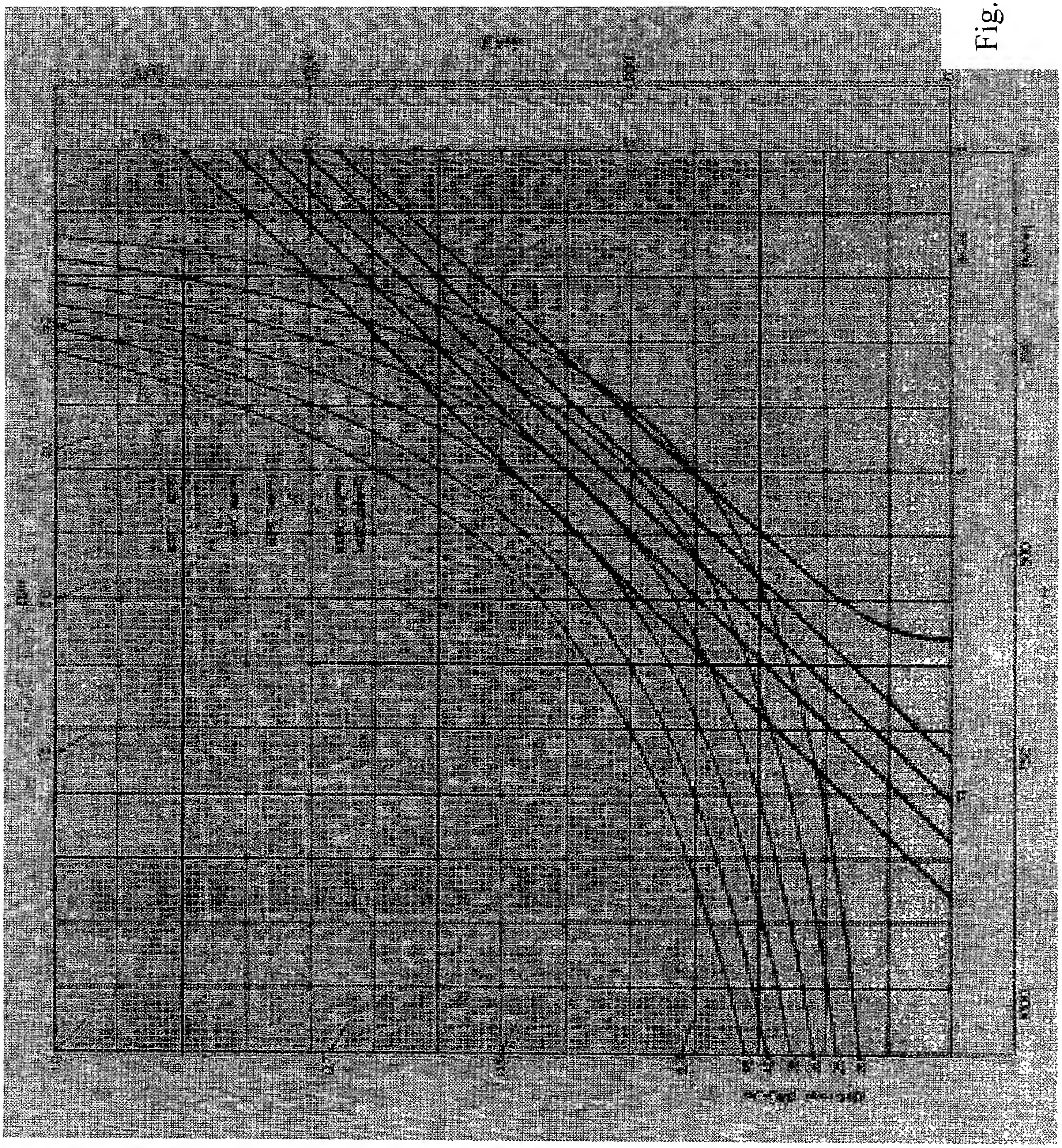
Fig. 1



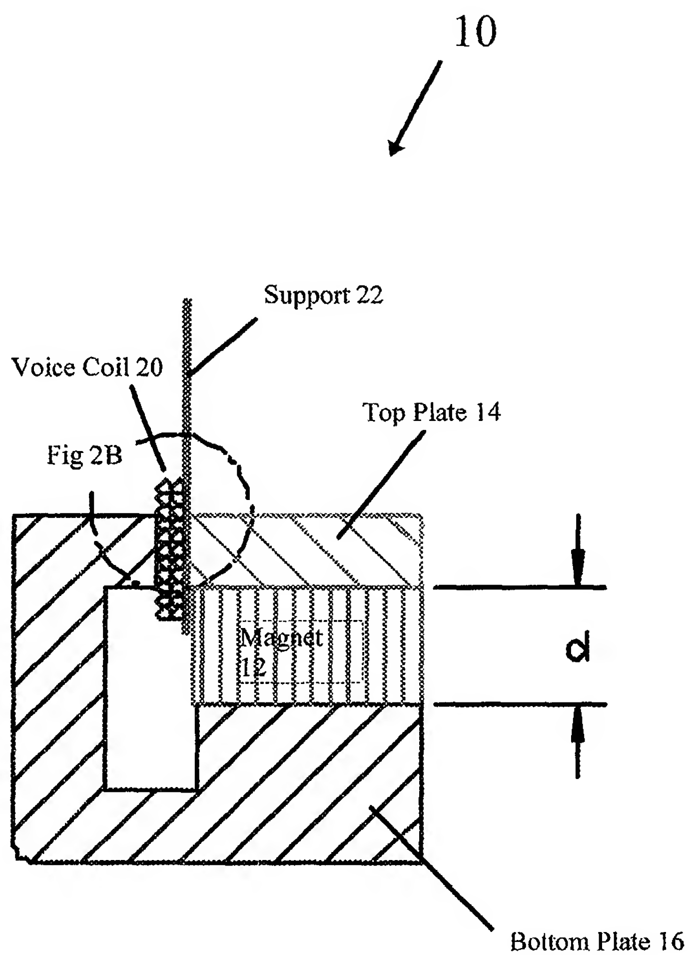


Fig. 2A

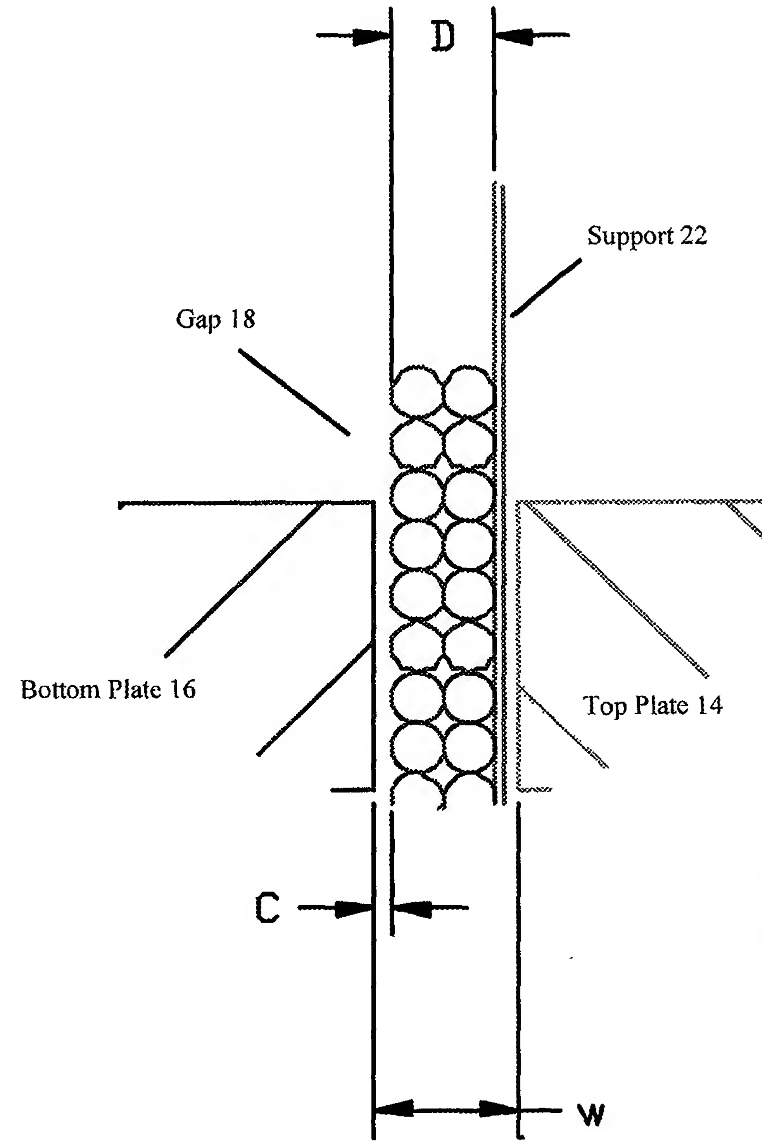


Fig. 2B

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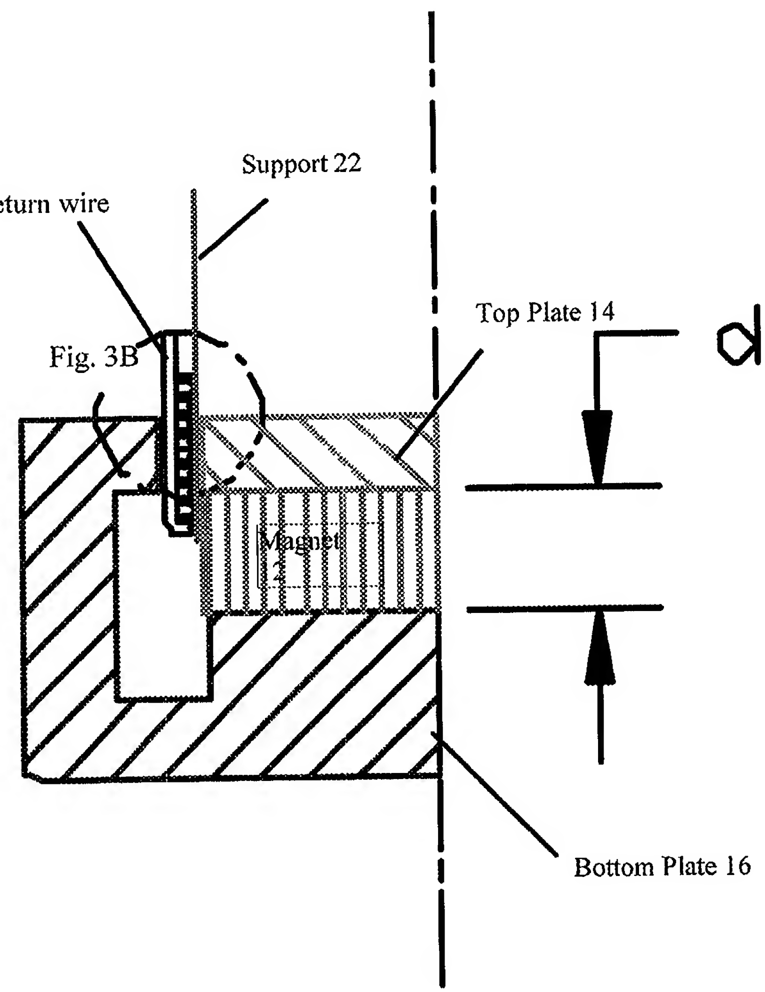

Fig. 3A

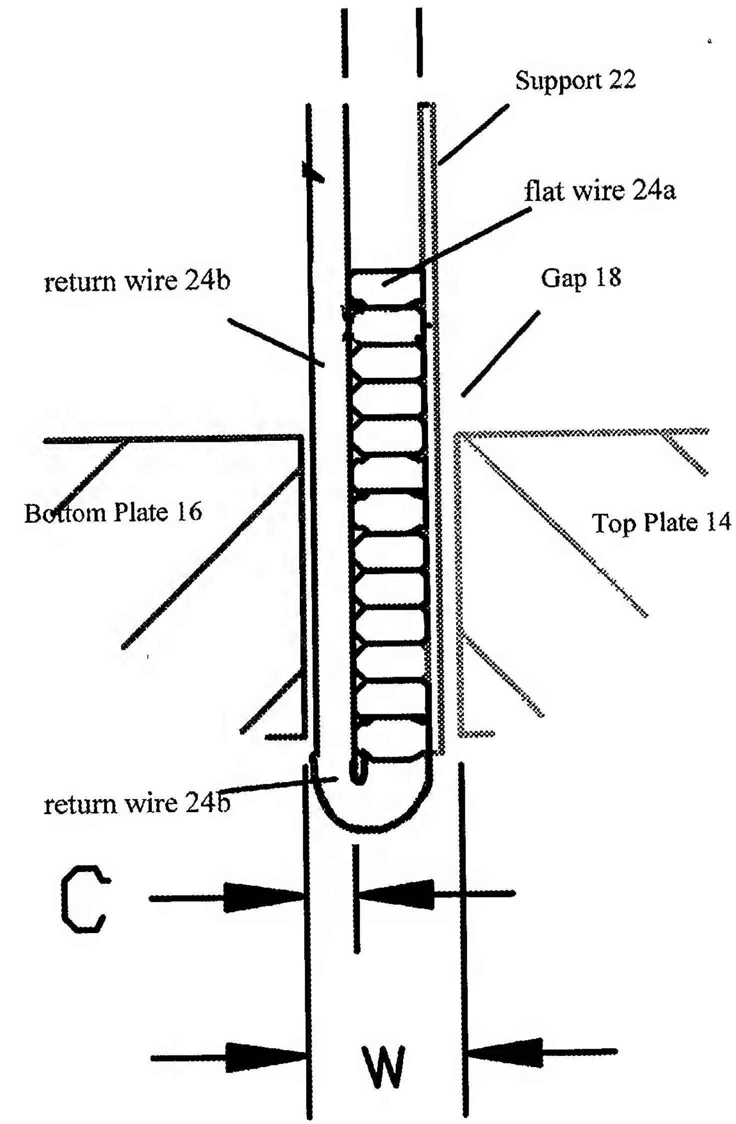

Fig. 3B

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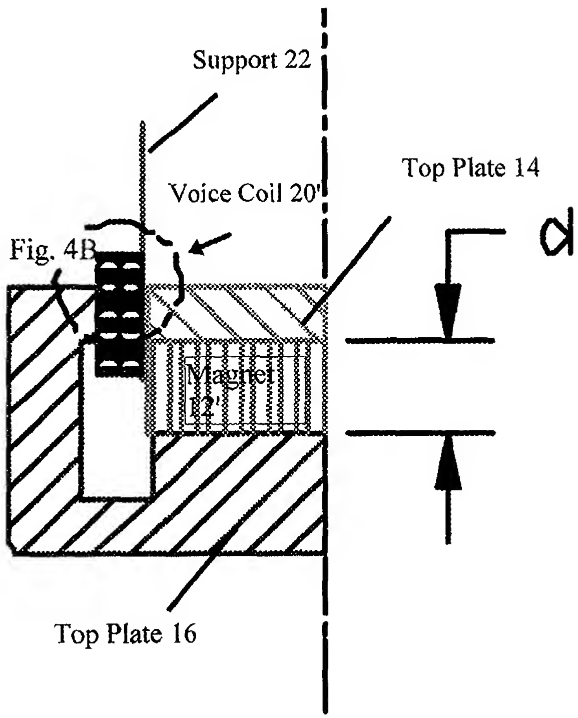

Fig. 4A

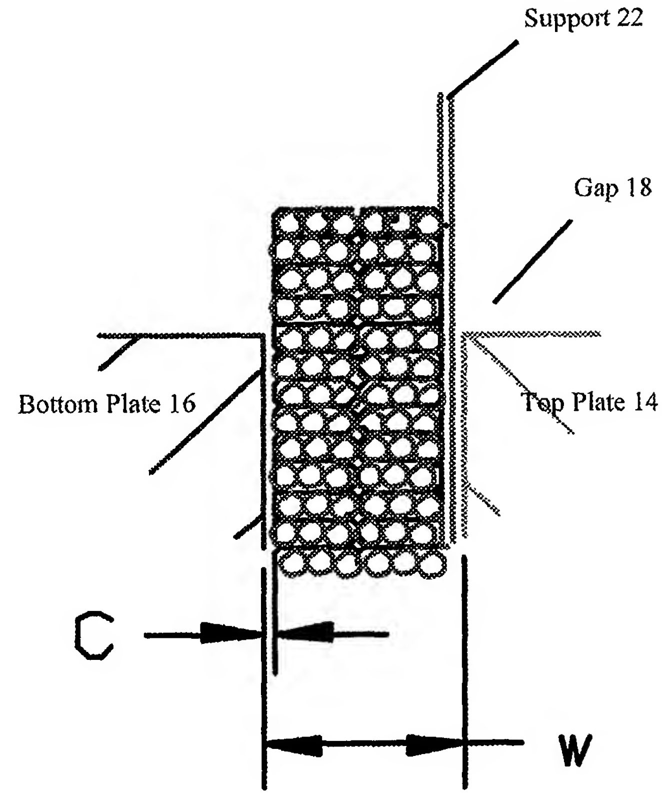

Fig. 4B

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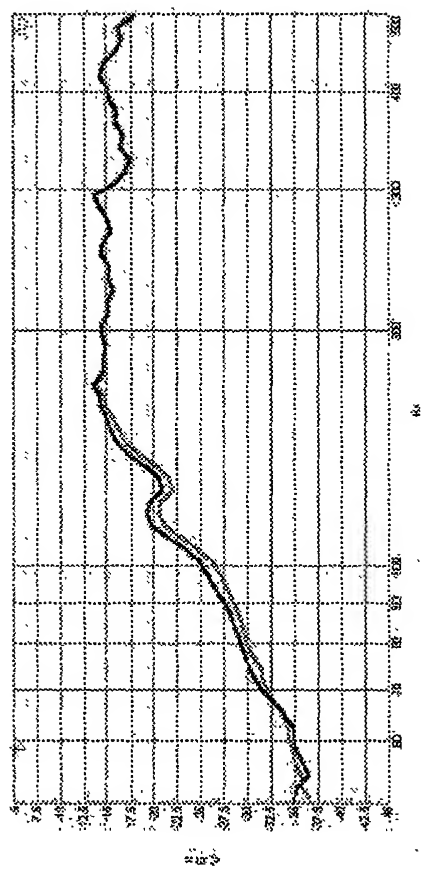

Fig. 5

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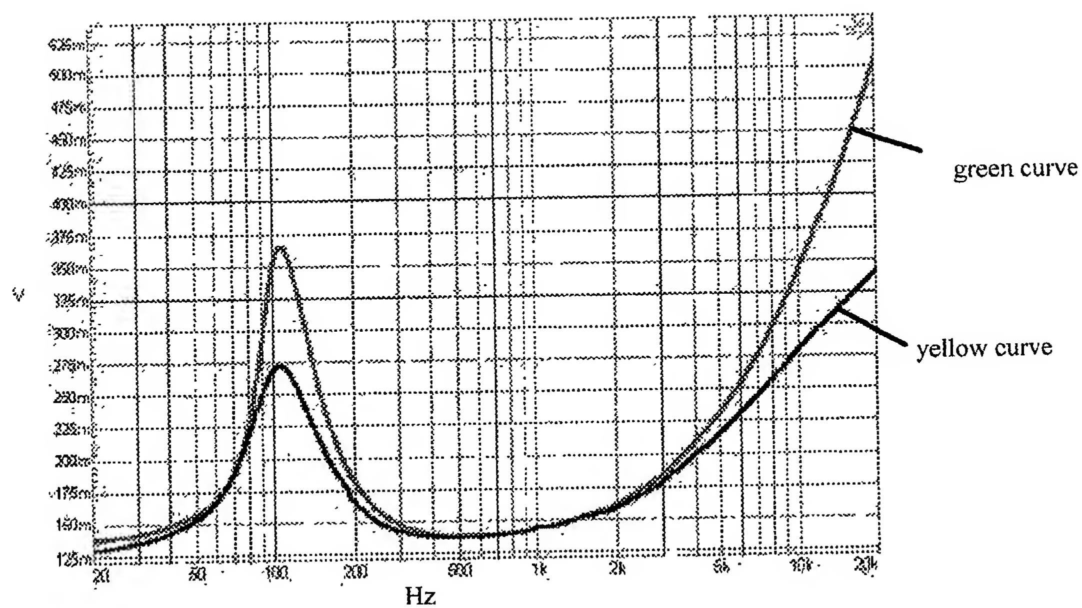

Fig. 6

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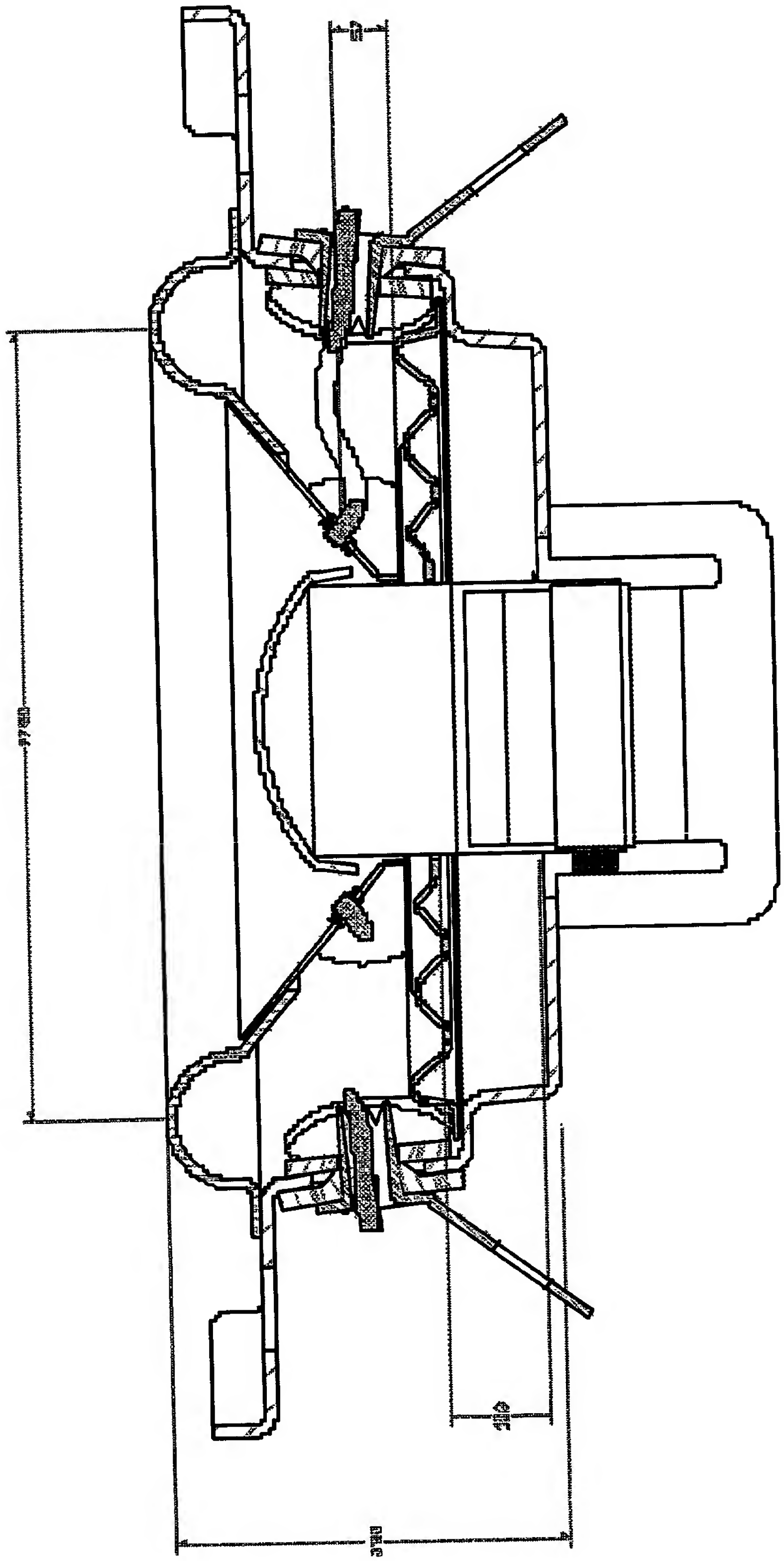

Figure 7